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TRANSPORTATION RESEARCH COMMAND  
FORT EUSTIS, VIRGINIA

## EXPERIMENTAL RESEARCH

### BREAKAWAY FUEL CELL CONCEPT

MAY 1962

Contract DA-44-177-TC-802

TREC Technical Report 62-37

276210

by :

CRASH INJURY RESEARCH  
PHOENIX, ARIZONA  
A DIVISION OF  
SAFETY FOUNDATION, INC.  
NEW YORK, NEW YORK

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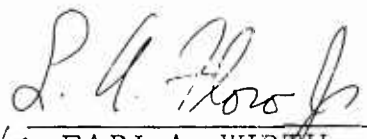
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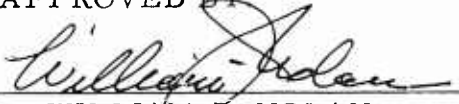
FOREWORD

This report was prepared by Aviation Crash Injury Research, a division of the Flight Safety Foundation, Inc., under the terms of Contract DA 44-177-TC-802. Views expressed in the report have not been approved by the Department of the Army; however, conclusions and recommendations contained therein are concurred in by this Command.

Fire has long been recognized as a major cause of injuries and fatalities sustained by personnel involved in aircraft accidents. This report presents Army statistics in this regard as compiled by the U. S. Army Board for Aviation Accident Research and offers a possible solution to the problem through the use of a fuel cell break-away concept. The results of a dynamic test of this nature are described herein and conclusions and recommendations made as a result of this test are reported.

FOR THE COMMANDER:

  
for EARL A. WIRTH  
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Adjutant

APPROVED BY:  
  
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USATRECOM Project Engineer

Task 9R95-20-001-01  
Contract DA 44-177-TC-802  
May 1962

BREAKAWAY FUEL CELL CONCEPT

AvCIR 62-3

By  
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## CONTENTS

	Page
FOREWORD . . . . .	i
SUMMARY . . . . .	1
CONCLUSIONS . . . . .	3
RECOMMENDATIONS . . . . .	5
INTRODUCTION . . . . .	7
DISCUSSION . . . . .	11
DISTRIBUTION . . . . .	17



## SUMMARY

In June 1961, Aviation Crash Injury Research (AvCIR), a division of Flight Safety Foundation, Inc., conducted a crash test utilizing an H-13G helicopter. An experimental breakaway fuel cell system, developed by the U. S. Army Board for Aviation Accident Research, was incorporated in this test.

Although the breakaway fuel cell system did not function as anticipated during the dynamic crash test, analysis of the test results indicates that the concept of the system is sound.

It is recommended that further testing of a breakaway fuel cell system, incorporating changes in the method of suspension of the system, be continued.

## CONCLUSIONS

Based upon the information contained in this report, it is concluded that:

1. The high rate of postcrash fire incidents experienced in Army aviation and deaths resulting from fire indicate a definite requirement for a practical method of fire prevention.
2. Dynamic crash tests of a breakaway fuel cell system indicate the feasibility and advantage of this type of system. Although the system did not function exactly as anticipated during the dynamic crash test, there was sufficient evidence to indicate that the basic concept of this system is sound.
3. The system can be designed to function as desired by modification of the breakaway tank suspension system.
4. The fiberglass tanks used in the test may offer additional advantages in that they did not rupture and create massive fuel spillage in the wreckage area.

## RECOMMENDATIONS

Based upon the foregoing conclusions, it is recommended that:

1. The concept of breakaway fuel cells as developed by the United States Army Board for Aviation Accident Research be further developed and tested during future crash tests.
2. A study be made to determine the feasibility of break-away fuel system installation on existing and future models of Army fixed- and rotary-wing aircraft.
3. Additional dynamic testing of the breakaway fuel cell system utilizing various methods of tank construction and tank suspension systems on both fixed-wing and rotary-wing aircraft be conducted. A simple drop test device can be utilized for this purpose.

## INTRODUCTION

The problem of postcrash fire is of primary concern in the design and manufacture of a crashworthy helicopter. With the expanding inventory of rotary-wing aircraft within the Army, one may project an increase of rotary-wing aircraft accidents and, from previous experience, a proportionate increase in accidents involving fire.

A review of Army aviation accident reports compiled by the Analysis and Research Division of the United States Army Board for Aviation Accident Research (USABAAR) indicates that postcrash fire is an important factor in occupant survival.\* The reports provide statistics concerning rotary-wing and fixed-wing accidents resulting in fire. The following table is a tabulation of major rotary-wing accidents and accidents in which fire was present during the period 1 July 1957 - 30 June 1960.

TABLE 1  
ARMY HELICOPTER ACCIDENTS INVOLVING FIRE  
1 July 1957 - 30 June 1960

Year	Total Accidents	Non-Fire Accidents	Fire Accidents
FY 58	174	158	16
FY 59	205	192	13
FY 60	200	187	13
Total	579	537	42

\*Army Helicopter Accidents Involving Fire, Report No. HF 2-60, Analysis and Research Division, Human Factors Section, United States Army Board for Aviation Accident Research, Fort Rucker, Alabama, 1960.

Army Fixed Wing Accidents Involving Fire, Report No. HF 1-61, Analysis and Research Division, Human Factors Section, United States Army Board for Aviation Accident Research, Fort Rucker, Alabama, September 1961.

During the period covered, 42 helicopter fire accidents were experienced. These accidents were broken down by type of aircraft (Table 2).

TABLE 2  
ARMY HELICOPTER ACCIDENTS INVOLVING FIRE  
1 July 1957 - 30 June 1960

Model	Total Accidents	Fire Accidents	Pct. Fire Accidents
H-13	231	12	5.2
H-23	113	7	6.2
H-19	55	4	7.3
H-21	101	9	8.9
H-34	58	6	10.3
H-37	9	2	22.9
HU-1A* (H-40)	11	1	9.1
YH-41**	1	1	100.0
Total	579	42	7

Fire accidents accounted for 7 percent of all major Army helicopter accidents. A similar percentage exists for civil rotary-wing accidents.

Damage from impact loads plus fire makes differentiation between ruptured fuel cells and ruptured fuel lines almost impossible in determining the basic fire causation factor. In Table 3, therefore, all fire accidents in which fire originated in the fuel cell area have been placed in the same category.

\* The one fire resulted from a grass fire which was ignited by the heater exhaust while the aircraft was parked.

\*\* The YH-41 was a test aircraft.

TABLE 3  
CAUSATION FACTORS IN HELICOPTER FIRE ACCIDENTS  
1 July 1957 - 30 June 1960

Fire Causation	No.	Pct. of Total Accidents
Ruptured Fuel Cells/Lines	33	78.5
Malfunction in Engine Compartment	7	16.7
Grass Fire (ignited by heater exhaust)	1	2.4
Unsecured Fuel Tank Cap	1	2.4
Total	42	100.0

During the period under study, the Army experienced 65 fatalities in rotary-wing accidents. Of these, 41, or 63 percent, occurred in postcrash fire accidents.

With regard to fixed-wing accidents, statistics obtained from USABAAR show that there were 488 major accidents during the period July 1957 - June 1960. Nineteen (3.9 percent) of these accidents involved fire and accounted for 35 percent of the fatalities sustained in all fixed-wing accidents. Ruptured components of the fuel systems caused a majority of fixed-wing fires.

It is apparent, then, that a reduction in the occurrence of fuel spillage would be instrumental in the prevention of helicopter postcrash fire and resultant fatalities. Due to the weight penalty imposed by installation of heavy, self-sealing fuel cells, another course of action was investigated -- the feasibility of breakaway fuel tanks.

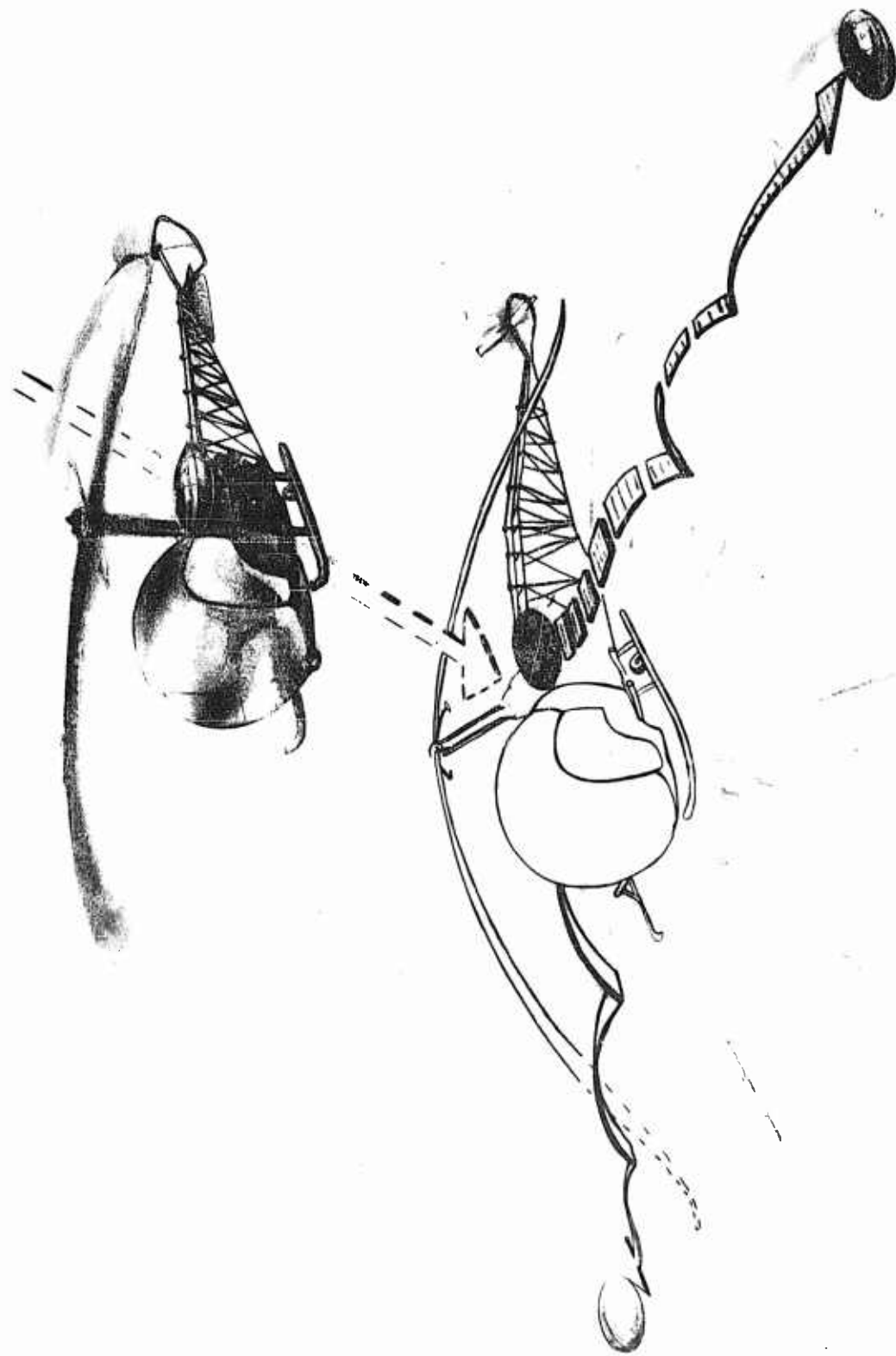


Figure 1. Design Criteria for Breakaway Fuel Tanks.

## DISCUSSION

Aviation Crash Injury Research, a division of Flight Safety Foundation, Inc., has conducted crash tests utilizing the Bell H-13G helicopter. Two sets of experimental fuel cells to be utilized for dynamic crash testing were developed and furnished by USABAAR. These 18-gallon fuel cells were constructed of fiberglass and were similar to the configuration of the metal tank currently installed on the H-13G.

The prime feature of the fuel cells was that they were to break away and tumble clear of the aircraft structure upon impact, thereby minimizing the possibility of a postcrash fire (Figure 1).

The breakaway fuel cell assemblies were installed on an H-13G helicopter, filled with colored water to simulate fuel, and tested during a simulated experimental crash. The fuel cells were mounted on cradle supports near the normal configuration; the exception was that the cell supports were tilted outboard in order to enhance the breakaway feature. A turnbuckle shear pin, designed to fail upon impact loads of 500 pounds, held the fuel cell retention straps in place. (See Figures 2 and 3.)

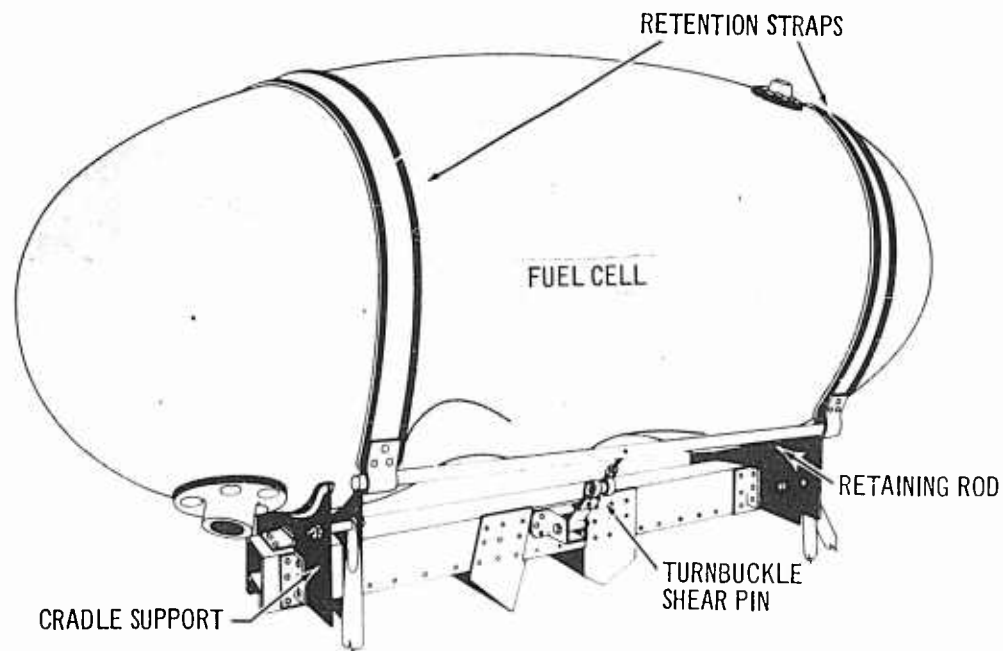


Figure 2. Location of 5G Turnbuckle Shear Pin.



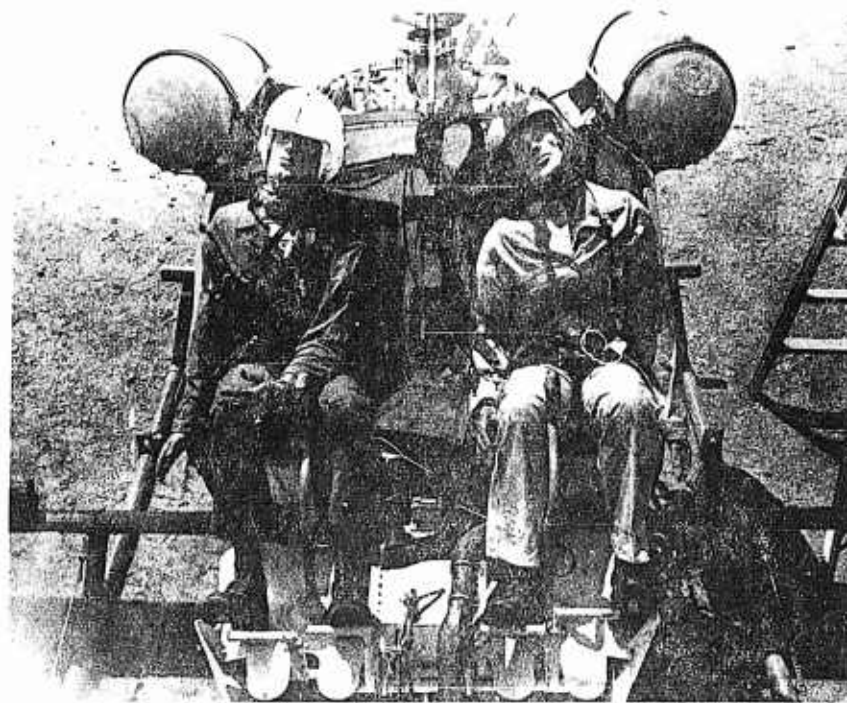


Figure 3. Front View Showing Position of Fuel Cells.

In making the drop, the helicopter was suspended from a moving crane and dropped on an asphalt runway (Figure 4). The helicopter was dropped from a height of 30 feet with a forward velocity of approximately 25 miles per hour. The rate of descent upon impact was computed to be approximately 2,600 feet per minute. The helicopter impacted in a near-level attitude with a final yaw of approximately 35 degrees to the left.

During the test, both fuel cells broke free from the fuselage cradle supports at impact. The right cell rolled away from the aircraft approximately 20 feet (Figure 6), but the left cell was caught between the left skid and cross-tubes and came to rest adjacent to the engine (Figure 7).

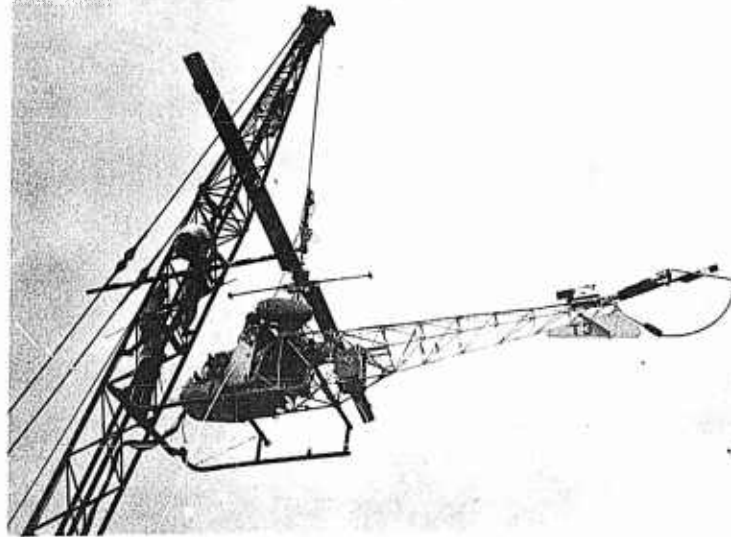


Figure 4. View of Helicopter Suspended From Crane Prior to Crash.



Figure 5. Postcrash View of Helicopter.

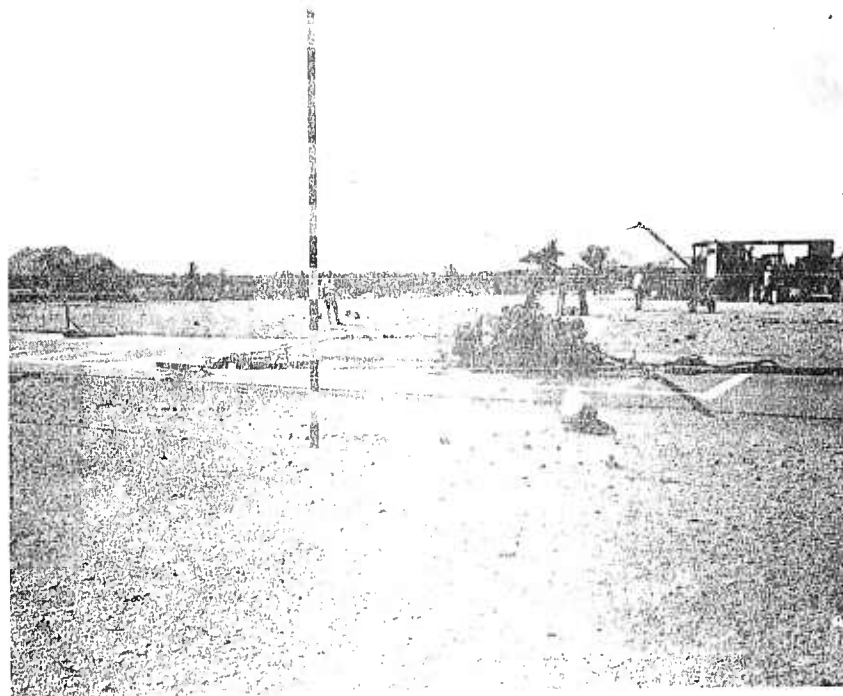


Figure 6. Post-rash location of Right Fuel Cell.  
This cell broke free and was located approximately 20 feet from the wreckage.

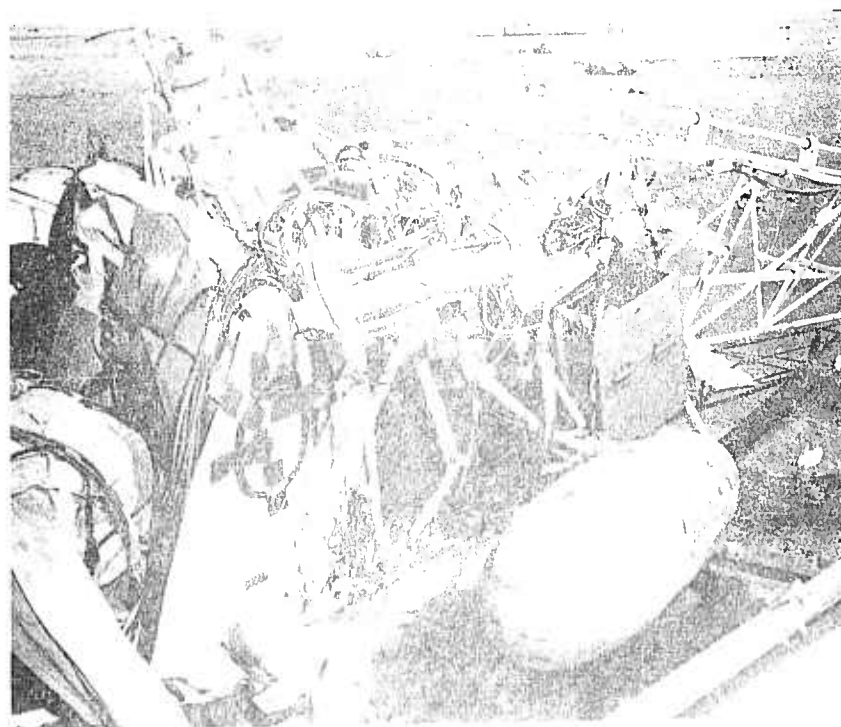


Figure 7. Location of Right Fuel Cell.  
This cell was located near the engine.

Postcrash investigation of this system revealed that the turnbuckle shear pins were still intact. The impact forces had bent the retaining rods to which the fuel cell retention straps had been attached, allowing the straps to become loose and thereby releasing the tanks before sufficient rotational force was developed in the straps to cause the shear pins to fail (Figure 8).

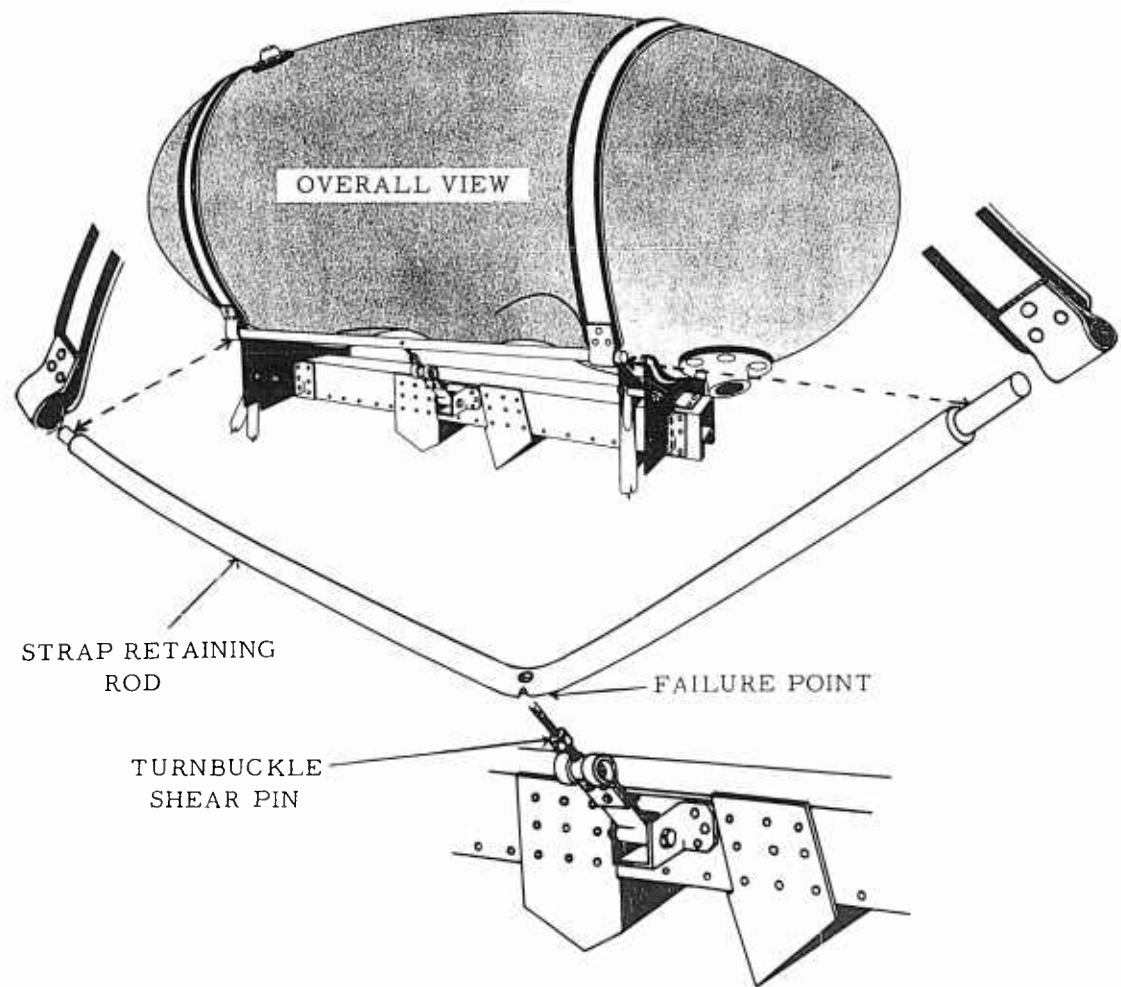


Figure 8. Strap Retaining Rod Failure.

Acceleration measurements were made in the longitudinal and vertical planes on the fuel cell support cradles, and force measurements were made on the fuel cell retention straps. Examination of the data revealed that vertical accelerations on the order of 30-40G were experienced in both the right- and left-hand cell supports, and longitudinal accelerations ranging from 20-30G were experienced in both locations. Peak forces of approximately 450 pounds were measured in the fuel cell retention straps.

The vertical accelerations resulted in considerable deformation of the fuel cell cradle support members and in the airframe structure to which these cradle supports were attached. During the action sequence, the retention strap retaining rods bent and slipped out of the strap ends before the strap loads reached the required 500-pound failure load for the shear pins. Figure 8 illustrates the manner in which these rods bent.

It is felt, however, that failure of the shear pin would not have changed the manner in which the cells separated from the aircraft. This is based on the fact that the energy represented in the cells during the drop was largely absorbed through deformation of the cell support cradles and the airframe structure to which the cell support cradles were attached, leaving very little energy remaining in the cells at the time of separation. The reason for the right-hand cell's tumbling some 20 feet from the wreckage is based on the fact that the aircraft yawed approximately 35 degrees during the crash sequence.

The foregoing indicates that the method for supporting the cells should be above and not below the cells so that when failure of the support system occurs, sufficient energy remains in the cells to provide separation velocity as the cells leave the aircraft structure. It is felt that an overhead support system coupled with an angled deflection plate below the cells will result in the cells' behaving as desired during a crash sequence. This and other methods for supporting the cells should be further explored.

Incidental to the breakaway feature of the fuel cells was the fiberglass material used in construction of the cell. The possible advantage of this material was demonstrated by the fact that the cells did not rupture upon impact with the cross-tubes or the runway. There were a few very small puncture holes in the left cell noted during the test. The "fuel" spillage was very small and presented a minimum fire hazard. It is felt that this type of tank construction should be further tested and compared with metal tanks.

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